Center Independent Research & Development: JPL IRAD

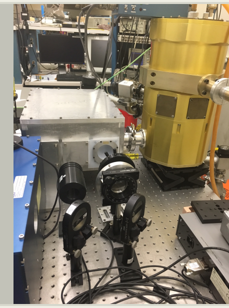
An Ultrabroadband THz Heterodyne Receiver With Reduced Cryocooling Requirements

Completed Technology Project (2015 - 2018)

Project Introduction

Laboratory terahertz (THz) heterodyne receiver with advanced capabilities that will be a prototype of the future instrument receiver for application in high-resolution spectroscopy of interstellar gaseous clouds. The new capabilities, which will be brought during this work, are the operation at around 4.7 THz (an important [OI] line), the extension of the intermediate frequency bandwidth of the THz heterodyne receiver up to at least 10 GHz (current state-of-the-art is < 4 GHz), and the possibility to operate a receiver at 20 K (current state-of-the-art is 4 K). These important capabilities have become available due to the use of a new superconducting material for fabrication of the THz hot-electron bolometer (HEB) mixer. HEB mixers are the only mixer type working with low noise at THz. The new material, magnesium diboride (MgB2), has a critical temperature of nearly 40 K.

THz spectroscopy is an important tool for studying star formation and evolution processes. JPL has been very strong traditionally in this astrophysical area, with major contributions in both science and instrumentation. JPL has delivered mixers and local oscillators (LO) for Bands 5,6, and 7 THz heterodyne receivers on HIFI/Herschel. JPL also works with University of Arizona on a heterodyne receiver array for Stratospheric THz Observatory (STO-2), a balloon project, and on the Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory (GUSSTO) for NASA's MO Explorer Program. A heterodyne instrument is an option on a future Origins Space Telescope to be proposed to the 2020 Astrophysics Decadal Survey. The new capabilities, which will be brought during our work, are the operation at around 4.7 THz (an important [OI] line), the extension of the intermediate frequency bandwidth of the THz heterodyne receiver up to at least 10 GHz (current SOA is < 4 GHz), and the possibility to operate a receiver at 20 K (current SOA is 4 K). These important capabilities have become available due to the use of a new superconducting material for fabrication of the THz hot-electron bolometer (HEB) mixer. HEB mixers are the only mixer type working with low noise at THz. The new material, magnesium diboride (MgB2), has a critical temperature of nearly 40 K. Our current R&D work has produced thin-film MgB2 mixer devices with a very high thermal relaxation rate that determines the large IF bandwidth. The expected impacts of the MgB2 HEB mixer technology on the future missions and program are very significant. The MgB2 material allows one to operate the mixer at a temperature as high as 20 K with a small sensitivity penalty. This temperature can be achieved in a relatively inexpensive way using well-developed space qualified mechanical cryocoolers. In this way, a space mission lifetime can be dramatically increased. The Herschel's mission lifetime (< 4 years) was limited by the capacity of the liquid He tank on board. Another impact is the increased IF bandwidth which will be now sufficient for capturing Doppler broadened spectra from multiple molecular clouds even at the higher frequencies of interests. Also during this work we are going to bring in a novel LO source based on the Quantum Cascade Laser (QCL). The QCL LO can be narrow tuned



Lab THz heterodyne test receiver featuring a hot-electron bolometer MgB2 mixer.

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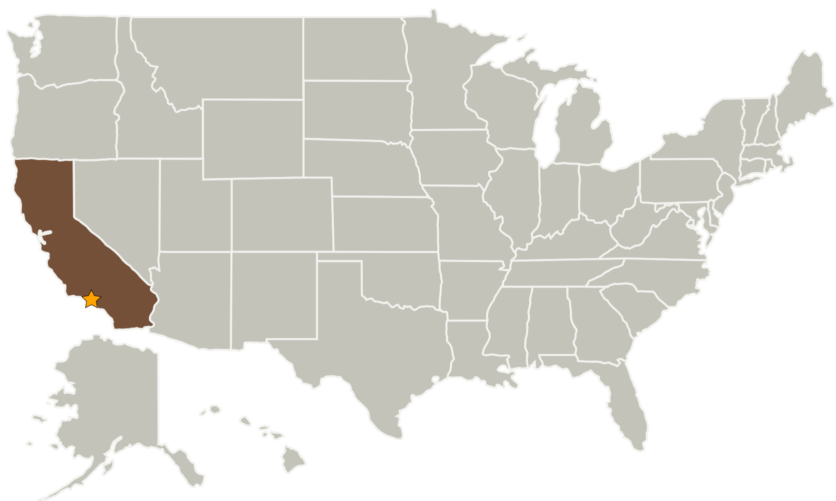
in the 1.5-5 THz range and operate at 50 K or even higher temperature depending on the frequency. The emitted power is close to 1 mW that is more than order of magnitude greater than the power available from the highest frequency JPL developed 2.5 THz sources based on Schottky-diode frequency multipliers. There are currently no 4.7 THz LO sources at JPL.

Anticipated Benefits

Benefits to NASA Unfunded & Planned Missions are the operation of the future space heterodyne receivers without the use of liquid He. Another benefit is an improved receiver bandwdith allowing the spectroscopy of very broad molecular lines in space at 3-5 THz.

The potential applications of the technology will be in the future heterodyne recievers (including array receivers) deployed on high-altittude balloons, SOFIA arocraft, and possibly in space.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

Fred Y Hadaegh

Principal Investigator:

Boris S Karasik

Co-Investigators:

Daniel Cunnane
Joanthan Kawamura
Jorge Pineda

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Primary U.S. Work Locations

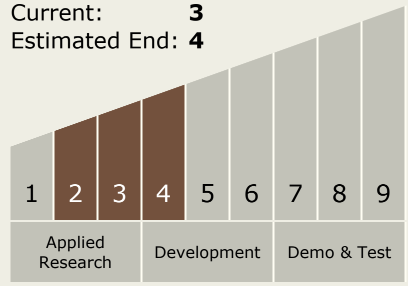
California

Images

THz receiver setup
Lab THz heterodyne test receiver featuring a hot-electron bolometer MgB2 mixer.
(https://techport.nasa.gov/image/24467)

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.1 Detectors and Focal Planes

Target Destination

The Moon

Supported Mission Type

Push